Ecology of Young-of-the-Year Fish in Muscote Bay (Bay of Quinte), Ontario.

J.K.Leslie and J.E.Moore

Great Lakes Fisheries Research Branch
Canada Centre for Inland Waters,
867 Lakeshore Road, P.O. Box 5050.
Burlington, Ontario. L7R 4A6.

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J. K. Leslie and J. E. Moore
Fisheries and Oceans
Great Lakes Fisheries Research Branch
867 Lakeshore Road
P.O. Box 5050
Burlington, Ontario L7R 4A6

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RÉSUMÉ

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Les poissons de l'année et le zooplancton ont fait l'objet de collectes systématiques dans la baie Moscote (baie de Quinte) entre avril et septembre 1981. Les poissons à l'état larvaire prédominaient à la mi-mai et au début de juin et le zooplancton était pour sa part très abondant au début de juin ainsi qu'en juillet. On a relevé 26 taxums de poissons; les espèces dominantes étaient la perche (Perca flavescens), le meunier noir (Catostomus commersoni), l'alose à gésier (Dorosoma cepedianum) et le faux-hareng (Alosa pseudoharengus). On a dénombré le plus grand nombre d'espèces entre le début et le milieu du mois de juin, tandis que la diversité la plus faible a été constatée au début de mai et en août. L'abondance et la diversité de presque toutes les espèces étaient plus grandes près de la côte que dans les eaux ouvertes à la navigation. Les cladocères, dont les Bosmina longirostris constituent le groupe dominant, représentaient de 43 à 86 p. 100 de tout le zooplancton, dont la diversité et l'abondance étaient remarquables, mais dont la distribution n'était pas uniforme. Les jeunes poissons semblaient avoir suffisamment de nourriture, mais il était évident que ceux-ci choisissaient et rejetaient certaines substances nutritives. Certaines espèces quittaient les eaux de la baie et d'autres venaient s'y établir. La baie Muscote servait dans l'ensemble de frayère, de même que de lieu où pouvaient grandir et vivre la majorité des jeunes poissons.

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ABSTRACT

Young-of-the-year fish and zooplankton were routinely collected from April to September, 1981, in Muscote Bay, Bay of Quinte. Larval fish were most abundant during mid-late May and early June; zooplankton peaked in early June and July. There were 26 taxa of fish, of which yellow perch, Perca flavescens, white sucker, Catostomus commersoni, gizzard shad, Dorosoma cepedianum, and alewife, Alosa pseudoharengus, were dominant species. Highest species diversity was in early to mid-June; lowest diversity occurred in early May and August. Abundance and diversity of virtually all species inshore exceeded those in open waters. Cladocerans, led by Bosmina longirostris, formed 43 to 86 percent of all zooplankton, which was notably diverse and abundant, but differentially distributed. Food for young fish was apparently sufficient, but selection and avoidance of certain food items was evident. Certain species were emigrants, others were immigrants. In general, Muscote Bay served as a spawning location, a nursery, and as a residence for most young fish.

INTRODUCTION

The Bay of Quinte, one of the most important centres of fish production in the Great Lakes, has been cited by the Great Lakes Fisheries Commission (1979) and the International Joint Commission (1980) as an area in which rehabilitation of major fish stocks is necessary. Details on the population dynamics of larval fish in the area are few, but are nevertheless required in order to understand temporal changes in species and community structure in an area currently undergoing declining environmental stress. The Bay of Quinte has a wide variety of habitat types, and has been studied intensively during the past decade. An extensive data base exists concerning its fishery (Hurley and Christie, 1977), benthic community (Johnson and Brinkhurst, 1971), aquatic ecology (Bristow et al., 1977; Nicholls and Carney, 1979), and nutrient input loading (Johnson and Owen, 1971). To date, only one larval fish study (Lam, 1977) has been conducted in the bay, and focussed mainly on the alewife, Alosa pseudoharengus. The present paper deals with species distribution and abundance in one particular area, noting some of the factors that may affect changes in populations of young-of-the-year fish in Muscote Bay, Bay of Quinte.

MATERIALS AND METHODS

Study area

Muscote Bay (44°06'N, 77°18'W) is located in a valuable commercial fisheries and recreational area of southeastern Ontario, and forms part of the upper section of the Bay of Quinte. This shallow, eutrophic water body, arbitrarily defined as the area enclosed within an imaginary

boundary transect from Cole Pt. to Horse Pt. (Fig. 1), has a total area of approximately 13.2 km^2. At peak water level in springtime, the maximum depth is 4 m, but during the rest of the year, the depth of virtually all of Muscote Bay is less than 2.5 m.

The main inflow to the bay is from two streams, Demorestville Creek in the southwest and Sawguin Creek in the west. These effluents effect water movement in the bay towards the northeast. Surface (if not all) flow was aided during the study period in 1981 by prevailing winds from the southwest in April, the south-southwest from May to September, and from the west during September (Environment Canada, 1981). A few small inlets and drainage ditches from bordering farms supply additional nutrient loads. The substrate varied from ooze to heavy, black, organic muck and clay at the mouth of creeks, and to rocks, gravel, and sand along exposed shores. Approximately 12 to 15 percent of the bay has emergent vegetation, mainly cattails (Typha spp.), and at least another 10 percent has submerged vegetation, chiefly Eurasian milfoil (Myriophyllum spicatum). Since the water mass in the shallow bay is well mixed as a result of winds, there is no thermocline, and dissolved oxygen is at saturation.

Site Descriptions

Six shore sites were chosen to determine if habitat preference occurred, and to detect temporal and spatial movements of young fish. The transect lines, Gravelly Pt. to Cole Pt. (G-C), and Sand Pt. to Richson Pt. (S-R; Fig. 1) were sampled in order to compare differences in species abundance in open water and shore areas, and to monitor transient movement of fish in the bay.

Cole Pt. (CP) is exposed to the western fetch of the wind; the bottom type was generally boulder and gravel with sand at the shoreline. The slope of the shore was gradual, with an exposed beach of less than 1 m. Physical conditions at Richson Pt. (RP) were similar to those at Cole Pt., although the water was not as deep and the beach more exposed, with a finer substrate of rock, sand, and clay.

Barnhart Island (BI) is directly affected by the influent of Demorestville Creek, which winds for several kilometres through an extensive marsh. Shoreline substrate was composed of a mixture of rubble and small rocks and sand, whereas black organic muck predominated at depths exceeding 0.5 m.

On the western shore, Sand Pt. (SP) was essentially exposed to the full fetch of the winds from the south. The water column at this site was usually heavily loaded with suspended organic matter, and the substrate was sand and clay. Water depth at Gravelly Pt. (GP) was usually 1 m for at least 100 m offshore, and the substrate mainly of clay, with a scatter of flat rocks and gravel at the shoreline. Submerged aquatic flora were less evident there than elsewhere in the bay. The shore station most sheltered from wind action was Sawguin Island (SI), at the mouth of Sawguin Creek (Fig. 1), and aquatic vegetation was prevalent there throughout the sampling season. Depth was usually less than 1 m and the substrate composed of heavy organic muck and large boulders. Both submerged and emergent vegetation were present, the abundance of which increased with water temperature.

Sampling and Analysis

In 1981, sampling for larval fish at six shore stations was accomplished with a fine-mesh (0.275 mm) seine, which was 3 m long and 1 m high (Leslie et al., 1983). Replicate samples from approximately 10-m hauls each at 0.5 m and 1 m were made every week during May and June, bi-monthly during July, and monthly in August and September (Table 1). During 1982, sampling was confined to Cole Pt., Gravelly Pt., and an associated transect, on May 21, May 25, June 2, and June 6; species presence, abundance, and size were compared with those in 1981. Equipment and techniques were the same in both years. Except where otherwise stated, descriptions and data refer to 1981. An assortment of auxiliary apparatus (various beach seines, hoop net, electroshocker, light and dark traps, buoyancy nets) was utilized to secure species of juvenile and adult fish from late summer to early winter at the sites and at a nearby marina.

Paired conical larval fish nets (0.5 m diameter, 2.5 m long) were used to sample surface waters along the two transects (Fig. 1). The nets were pushed at each side of a 6 m Boston whaler, which was driven by a 75 HP outboard motor. Boat speed, 1.0 $m.s^{-1}$ was determined by a hand held direct reading current meter (Leslie and Leslie, 1980). Identical nets of 0.36 mm mesh were used from May until mid-June, when high concentrations of suspended particles and zooplankton forced a change to a pair of 1 mm and 0.36 mm mesh nets. These were used until regular sampling terminated in September. Duration of tow was 2.5 min, and a total of six replicated paired tows were taken, two near each end and at the centre of the transects (Fig. 1). Other paired conical nets (mesh: 2

x 1 mm) were towed during high-speed sampling, both at the surface and at selected depths. Samples were pooled, except where comparative tests with different nets were made, and fish were fixed in formaldehyde diluted with habitat water to approximately 10 percent. Samples were stored within 1 day at 4°C, larvae picked from debris, and preserved within eight months in Davidson's B.

Sampling was concentrated in May and June, the period during which most species were present in the larval stage, and thus most susceptible to samplers. Transect samples were obtained in ten consecutive weeks, and shore stations were sampled nine weeks in succession. Seining also took place at a nearby marina, where there was an abundance of fish from September to December, to enable estimation of growth characteristics of some of the young-of-the-year fish species, notably yellow perch.

All larval fish were examined, and identification was aided mainly from descriptions given by Fish (1932), Hogue et al. (1980), Lam and Roff (1977), Norden (1961), and Snyder et al. (1977), and comparisons with local reference specimens. Thirty larvae (or total number in samples with fewer fish) were measured in each sample. Approximately 6,000 fish were measured (to the nearest 0.1 mm), using a dissecting microscope, equipped with an ocular micrometer. Total length (TL) of juveniles was the maximum horizontal length (nearest 0.5 mm) between anteriormost tip of mouth and caudal fin in natural attitude. Measurements were not corrected for short-term changes that may occur due to preservation; such changes are generally in the order of two percent (Leslie, 1983). Lengths, unless otherwise noted, are in total length; abundances are given as number of larvae per 100 m^3.

Zooplankton samples were taken, using the sampler illustrated in Figure 2, coincident with larval fishing, with the intention of providing a possible insight into the feeding regime and influence of food on larval fish. Plankton were preserved with sugared four percent neutral formalin for later classification and quantification.

Feeding

The following species were analyzed for gut contents: yellow perch (Perca flavescens), white sucker (Catostomus commersoni), alewife (Alosa pseudoharengus), brook silversides (Labidesthes sicculus), white perch (Morone americana), and lake whitefish (Coregonus clupeaformis). The entire digestive tract was removed from each fish and all identifiable items therein counted; it was assumed that capture did not induce regurgitation. The total size range of available fish was examined, and where possible, at least 25 specimens from each size class were selected. Of the total of 1,298 guts examined, 855 were of yellow perch. Food organisms were generally identified to genus.

Zooplankton Counting

Samples were counted using the procedure described by Borgmann et al. (1984). The fraction of the sample counted depended on the species, at any given time varying from the whole sample for the least abundant forms, to as little as 1.25 percent for the most abundant. Immature copepods (copepodites and nauplii) and ostracods were counted and identified only to order; everything else was identified to species.

Abundance Estimates

Abundances were calculated for the transect samples by assuming that the fish caught in a net tow represented those in a volume equal to the product of the mouth area and the distance towed. Typically, 45 m^3 were filtered in 2.5 min. Filtration efficiency was assumed to be 100 percent.

For the beach seines, the volume sampled was assumed to be the length of the net times the depth and length of the haul, i.e., 15 and 30 m^3 for the shallow and deep hauls, respectively.

Statistical Analysis

Raw catch data transformed as ln (numbers +1) were used in the analyses, treating shore data and transect data separately. Data within these two groups were further arranged to give total catch (exclusive of white suckers) and to give the catch of three of the four most abundant species, yielding a total of eight sets to be analyzed. Dates without a catch were omitted from the analyses. Depending on the comparison being made, some of the earliest transect data also had to be omitted because of missing samples.

Within each set, three factors were examined. For the shore data these factors were replication, station, and depth, while for transect data they were replication, transect, and portion of transect. To make the most of the data, each factor was examined separately, an approach which requires that there be no interaction between the factors. This assumption was validated by the results of a three-factor factorial ANOVA carried out on each of the sets, regarding dates as blocks to remove the effect of seasonality.

Two-tailed paired t-tests were made for all comparisons, except for those between shore stations, and those between transect portions, for which two-way ANOVA was used. When comparing shore sample depths, the data were weighted by doubling the 0.5 m values to compensate for the smaller sample volume. To facilitate discussion, the magnitudes of any differences observed in the paired comparisons were converted back to the original scale of measurement so that a difference became approximately the ratio of geometric means. This ratio is referred to as a geometric mean factor (GMF) in what follows.

Other Observations

In order to further help explain larval fish population dynamics, water temperature at 0.5 m and climatological observations were taken during larval fish sampling. These results are presented in Table 2.

RESULTS AND DISCUSSION

Crustacean Food of Young Fish

There were 35 species of crustaceans in surface collections taken from May 26 to September 9 at eight larval fish sampling locations (Fig. 1). Twenty-six species of cladocerans and nine species of copepods are listed in Table 3, including cyclopoid and calanoid copepodites and nauplii, harpacticoid copepodites, and an ostracod species.

There was considerable spatial differentiation of the zooplankton, both in terms of species diversity and abundance, a condition common in small bodies of eutrophic water (Lewkowicz, 1974). Notable differences existed between opposite sides of the bay, as well as between adjacent

shore stations and transects. In this respect, there were 13 species that were not shared by east and west shore stations, nine of which were present at the western shore, but absent across the bay. Five species present at Gravelly Pt. were absent at Sand Pt., only 1.8 km away. Similarly, eight species were not shared by transect sites, only 2.3 km apart.

Sawguin Island, with 31 species, led all sites in diversity, and Richson Pt., with 19 species, had the fewest. Cladocerans comprised more than 70 percent of the zooplankton on all but three sampling dates (Table 4), whereas cyclopoids formed most (51 percent) of the crustacean population only on June 16. Less than two percent of the population consisted of calanoids and ostracods.

Cladocerans

During late May, early June and July, cladocerans greatly exceeded copepods in abundance (Table 4). Eight cladocerans appeared at all sampling locations. A single species, Simocephalus serrulatus, was exclusive to the pelagic area, but was not abundant.

Cladocerans were in greatest abundance from May 26 to June 2, and on July 7, and were least abundant on August 25 (Table 4). Dominant species, led by Bosmina longirostris, comprised 90 to 100 percent of cladocerans and 43 to 86 percent of all the zooplankton.

The number of Bosmina longirostris peaked on July 7, when water was 27.9°C at Gravelly Pt. This species exemplified the wax and wane of many species throughout the season (Table 4). Patalas (1969) noted peak abundance of B. longirostris prior to maximum temperature in Lake

Ontario; in Muscote Bay, however, the population and maximum mean temperature (27.1°C) peaked coincidentally. Hatching and development of zooplankton were enhanced by prolonged high water temperature, which for six consecutive weeks exceeded 21°C.

Eubosmina coregoni ranked second in abundance (Table 3), reaching a peak on May 26 of 35 percent of the zooplankton and a low of less than one percent on September 9. This species was found mainly at Gravelly Pt. and nearby open waters, but were fewest at Barnhart Island. Abundance at shore stations fluctuated more than at open water locations. After July 21, E. coregoni was virtually absent in shore samples.

C. sphaericus appeared more or less consistently at all sites, but was mostly present at Gravelly Pt. and in transect waters.

Daphnia retrocurva and D. galeata mendotae ranked in abundance fourth and fifth, respectively, and both peaked on June 2, but did not appear in samples after July 21. Daphnia spp. were mostly located in the open waters of the bay.

Cyclopoids

Most species of copepods were at Sawguin Island and in surface waters between Sand Pt. and Richson Pt., although densities were not, in general, high (Table 4).

Cyclopoid copepodites and nauplii ranged from 10 percent (July 7) to 51 percent (June 16) of the total zooplankton in the bay. Copepodites and nauplii were seldom in approximately equal abundance; initially (May 26) nauplii consisted of 59 percent and copepodites 38 percent,

respectively, of all copepods. This proportion was reversed by June 9, i.e., 34 percent nauplii and 64 percent copepodites.

It is apparent that whatever the individual abundance of zooplankton species, larval fish are probably adequately served by the sheer number of individuals and the broad size range of food items available.

LARVAL FISH

A total of 68,000 larval fish were caught during the regular sampling periods from April to August, 1981 (Table 1), and 3,500 from May 13 to June 9, 1982. Forty-eight thousand fish were from shore seining, nearly twice the number obtained in transect locations. Several thousand juvenile fish were also caught during qualitative sampling. A check-list of species by week over all sites in the bay is given in Table 5. Larval fish first sampled were yellow perch, lake whitefish, and white sucker, all of which were taken during April 30.

Main species

Perca flavescens

Life History and Habits

Average spawn: gelatinous mass of ca. 23,000 eggs in water 8.9 to 12.2°C, usually over rooted and submerged vegetation (Scott and Crossman 1973). Hatching: one to several weeks; newly hatched remain a few days on spawning grounds; nursery habitat largely dependent on currents; older larvae become benthic in four to five weeks and shelter in nearshore areas (Goodyear et al., 1982).

Population Dynamics

Mean abundance of yellow perch peaked in mid-May, having increased ten-fold from its initial appearance on April 30 (Table 6). Between July 6 and August 24, none were caught in the bay, although during this period juveniles were seined in a nearby marina. Sites with higher than prevailing water temperature in the bay may be expected to incubate eggs earliest, since faster warm-up of water in a suitable area induces earlier spawning and peak abundance (Amundrud et al., 1974). Temperature was highest (20.8°C) at Gravelly Pt. on May 20 (Table 2), when abundance there peaked, whereas at Sand Pt., temperature was 15.5°C and abundance correspondingly low. Hatching in Demorestville Creek and associated marsh probably occurred during mid to late April, assuming an incubation period of eight to ten days (Scott and Crossman, 1973). Presence and peak abundance of young yellow perch and other main species are listed in Table 7.

Larvae were first sampled on April 30, when they were planktonic. Maximum abundance occurred on May 20, when there were 3,357 larvae/100 m^3 at Cole Pt. Maximum densities were thus comparable with those reported by Loftus (1978) of Lake Huron perch (20 to 83/m^3 and by Jude et al. (1980) of Pigeon Lake, Michigan, perch (4,200/100 m^3). None were caught offshore later than June 9, and the latest catch of this species during regular sampling was on August 24. Of a total catch of 37 larvae on June 9, 1982, most (30) were seined at Gravelly Pt. Extensive seining in late autumn along the shores of the bay and islands therein resulted in a catch of few juveniles. Best and positive results were always at a marina, where juveniles were abundant.

Replicate catches differed significantly at shore sites, but not significantly in the transects (Table 8). On average, the first catch at the shore exceeded the second by a geometric mean factor (GMF) of 1.42; the corresponding factor in transect samples was 1.22. The shore data probably reflect removal of catchable fish by the first haul and avoidance by larvae of the area disturbed by that haul.

Shore hauls at 1 m usually caught more larvae than at 0.5 m (GMF = 3.12). This effect was significant ($P<0.01$) and suggests avoidance by larvae of the very nearshore area.

Highest catches were at Gravelly Pt. and Cole Pt., moderately high at Richson Pt. and Barnhart Island, but low at Sand Pt. and Sawguin Island. The variation between all shore sites was significant at the one percent level. Comparison of the outer (G-C) transect with the inner (S-R; Fig. 1) revealed significantly ($P<0.05$) more fish caught in the latter with a geometric mean ratio of outer to inner of 1.59. Samples showed a tendency for there to be more yellow perch caught near the shores than in the centre of a transect, and especially more near the west shore, but the differences between transect portions were not significant (Table 8). Greatest success in seining larvae at the shore, which forms a natural sampling barrier, occurred from hatch in late April to early June, when perch were about 12.9 mm (Table 9). Thereafter, ability of young fish to evade seining increased with size.

After a few weeks in the Barnhart Island area, most larval yellow perch abandoned it as a nursery, but retained the apparently more suitable habitat, Richson Pt. (Fig. 1). Barnhart Island, probably a good nursery area for this species insofar as the early period of development

is concerned, is shallow, protected from effects of wind, and affords good shelter, especially for protolarvae. Stereotaxis may account somewhat for the apparent greater abundance of larval perch along the shoreline, as compared with open waters of the bay. They were frequently caught with several other species of various sizes at all sites. In early June, they were associated mainly with gizzard shad and white perch, but occasionally with as many as eight other species. Young perch tend to be distributed contagiously, especially in nearshore areas (Patterson, 1979). Indeed, large concentrations of them (ca. 18 mm) were visible at the shore of Cole Pt. during bright sunlight at noon, but similar densities were not seen in open waters of the bay. Coles (1981) reported an onshore migration in early July of postlarval Eurasian perch, few of which exceeded 18 mm. Using several sampling devices, Coles found that age 0+ populations were not present in the pelagic region after mid-July, and by the end of August, none were caught in shallow waters. In Muscote Bay, larvae favoured shore areas, but juveniles moved to cooler, deeper water, or possibly left the bay in late summer. There did not appear to be any onshore migration, however. The number of suitable habitats for young perch probably shrinks with increased water temperature, and the consequent propogation and growth of macrophytes. Although high speed tows were made in the pelagic area during July and August, no perch were caught. There is little doubt that routine sampling methods failed to capture the fast-swimming juveniles.

Several studies agree that the general distributive pattern of larval yellow perch is to concentrate in shallow inshore water (Faber, 1967; Noble, 1972; Heniken, 1977; Cooper et al., 1981). Noble (1972) noted

greater tendency for distribution of perch at the surface in calm water, whereas Heniken (1977) and Cooper et al. (1981) found them concentrated near the bottom. Coles (1981) found the distribution of early larvae and post larvae of perch, P. fluviatilis, related to the effect of winds, as did Houde (1969) of yellow perch in Lake Oneida, New York. The distribution of larval fish in shallow waters is somewhat reflected by the immediate past history of winds, i.e., hours prior to sampling. Because most winds in Muscote Bay prevailed from the south-southwest (Environment Canada, 1981) during spring and summer and were seldom calm, they may be expected to concentrate larvae at the eastern shore. As already noted, however, yellow perch larvae in Muscote Bay tended to be more abundant at the western ends of the transects than at the eastern ends.

Feeding

On May 1, yellow perch (4.3 to 7.1 mm; x = 6.1 mm), commenced feeding mainly on Cyclops spp., but to a minor extent also chose phytoplankton, eggs, and rotifers; about half of the guts contained no food items. During the first week in May, the occurrence of feeding on copepods increased from 31 to 86 percent when larvae were 5.6 to 8.8 mm (x = 7.1 mm). A week later, at 9.0 mm (Table 9), larvae fed almost exclusively on Cyclops spp., and by May 21, had started to switch to Bosmina spp., selecting as such 17 percent of their food items, and 78 percent of Cyclops spp. This feeding regime continued for another week, when larvae were 10.5 mm.

Zooplankton and larval yellow perch peak abundance coincided in late May and early June (Fig. 3), a significant time at or near the so-called "critical period" (May 1974), when larvae have exhausted their supply of yolk and must resort to exogenous feeding. To enhance survival during this period, larvae must have a food supply that is abundant and appropriate in size and nutritional value. Table 10 lists major food items of yellow perch (8.7 $\pm$ 0.7 to 18.9 $\pm$ 1.0 mm).

Nowhere in the total size range was there exclusive selection by yellow perch of a particular species or size of plankter. Cyclops spp. were usually the main food of small larvae, and Bosmina spp. of larger larvae. These results generally parallel those of Siefert (1972), who observed first feeding of yellow perch at 6 mm, prior to yolk absorption at 7.1 mm. However, Bulkley et al. (1976) found 8.7 mm perch first eating copepod nauplii, and later, at 26.4 mm, choosing Cyclops 50 percent of the time, and Diaptomus (33 percent), while ignoring Bosmina. Muscote Bay larvae of 26 mm almost exclusively ate Cyclops spp. (91 percent of the diet), and Daphnia spp. (7 percent), but at ca. 33 mm, switched back to Bosmina spp. Coincidentally, Bosmina spp. outnumbered cyclopoids by a factor of four. In contrast, perch (30 to 35 mm) in Oneida Lake, New York, shifted feeding preference from 1.0 mm Diaptomus minutus to the larger (2.3 mm) Daphnia pulex; this shift was not a function of fish size, but was possibly linked with optimum foraging strategy (Mills et al., 1984). Chydorus sphaericus (56 percent), Bosmina spp. (35 percent), and Cyclops spp. formed the diet of slightly larger juvenile perch (41-47 mm; N = 5).

The abrupt decline in population of certain species of zooplankton upon which yellow perch larvae feed in early summer, may be related to feeding of other species of larval fish or to adult perch, which feed intensively on zooplankton, especially Daphnia spp. (Noble, 1975). Mills and Forney (1983) determined feeding pressure by perch on Daphnia pulex caused its disappearance during late summer. In comparison, no single zooplankter was similarly affected by perch in Muscote Bay.

Selection of specific food items did not coincide with the potentially most abundant food available. For example, at Gravelly Pt., the index of electivity (Ivlev, 1961) was +0.97 for Daphnia sp., which comprised 14 percent of the total zooplankton; at Cole Pt., Daphnia sp. had an electivity index of +0.52 when only four percent were present in the environment, and at Sand Pt., the index for Cyclops sp., was +0.78, when this species comprised nine percent of the total zooplankton in the environment. Similarly, Cyclops sp. at transect G-C had an index of +0.76, whilst forming 28 percent of the zooplankton. On June 8 at Barnhart Island, there was an index of +0.73 for Daphnia sp., -0.81 for Cyclops sp., and -0.52 for Bosmina sp., when larval perch were 20.2 mm. The index indicated no clear evidence in early June for preference of any of the three major food items. As larvae grew, they started to show interest in Daphnia spp. (Table 10), which eventually becomes a principal item in the diet of both young and adult perch (Noble, 1975). Shifts in feeding probably effected the virtual disappearance of larvae from surface waters in mid-June. Demersal zooplankters can attract perch of 25 mm (Noble, 1975), and may have induced them to feed in deeper waters adjacent to Muscote Bay.

Growth

One third of the total length (70.1 mm) on September 26, 1981, was attained during the second week of June, and two-thirds during the third week of July. Half the total length was attained during the first nine to ten weeks. In comparison, perch in Lake Windermere achieved more than half their growth in length during the first six to eight weeks (Guma'a, 1978), and in the Red Lakes, Minnesota, 46 to 68 percent of the first year growth (74.7 mm), was completed in the first eight weeks (Ney and Smith, 1975). Larvae increased in length during the first three to four weeks at a low, rather constant rate, i.e., ca. 0.2 mm/d, when yolk is resorbed, and exogenous feeding initiated. In early May, larvae are in the critical period, and factors other than food can drastically alter the growth rate. Temperature and wind at this time fluctuated considerably (Table 2; Fig. 4), which may have contributed to pauses in the rate of growth. Wind-driven larvae and zooplankton can be separated, causing scattering of the food resource, with ultimate consequences for the year class.

Whereas the increase in length of perch during the complete sampling period in the Red Lakes was essentially linear with time (Ney and Smith, 1975), and logistic in Lake Windermere (Guma'a, 1978), the rate of increase of Muscote Bay larvae was characterized by irregular pauses and spurts during the growing season, arbitrarily taken as extending to late September or early October. Between mid-May and early June there were several variations, which were similar in both years (Fig. 4). Notably, during July 7 to 21, the highest rate of change in length was 1.29 mm/d, and occurred when zooplankton density fell from a peak on July 7 to a low

level two weeks later. Unfortunately, the cropping pressure of yellow perch alone was unknown. The asymptote of growth in length appeared to be reached in late September, 1981, and mid-October, 1982 (Fig. 4), but the length data may be affected by trawling operations in the autumn, when larger juveniles are sometimes caught.

Catostomus commersoni

Population Dynamics

In Muscote Bay, suitable lotic spawning sites for this adfluvial species were limited to Demorestville Creek and Sawguin Creek (Fig. 1). Although the second most-abundant species in our catches, white sucker were spatially incidental and temporally ephemeral. Initial appearance was on April 30 at Barnhart Island, when, at a mean length of 13.8 mm, water temperature was 12.8°C. Peak (and final) appearance at Barnhart Island occurred on May 26 (Table 6), when larvae were 17.7 mm, and water temperature was 20.0°C. On this date, roughly one quarter of all larvae caught in Muscote Bay were suckers, obtained during a single beach seine at 0.5 m. This species was otherwise generally absent in the bay (Table 5), especially in open waters, where they were not found after June 1, 1981. Sixteen larvae ($\bar{x}$ = 25.0 mm) were caught at the shore on June 9, 1982.

The apparent absence of white sucker in offshore water corresponds with the findings of Lam (1977), who caught only three larvae during extensive open water sampling (May to September, 1974) throughout the Bay of Quinte. During their peak abundance in Muscote Bay, larvae were concentrated to an extent that virtually darkened the water at a depth of

ca. 30 cm, two metres from shore, in emigration from Demorestville Creek. In addition, many other schools were noted in the shallows of sheltered and shaded water at Sand Pt. in mid-May. Extensive beach seining in late summer and autumn failed to catch any juveniles, and in late spring, suckers probably deserted the warm, shallow bay for deeper, cooler water.

Feeding

White sucker apparently start feeding at 12 to 13 mm, just prior to yolk absorption at 14 mm (Siefert, 1972). Food of the smallest Muscote Bay larvae examined (13 to 14 mm; N = 75) was chiefly the Cladocera (Table 11), with lesser amounts of rotifers (11 percent) and Cyclops sp. (6 percent). Corbett and Powles (1983) noted a similar feeding regime, which was associated with surface feeding. It is notable that two groups of 14.1 mm larvae sampled just three days apart at a marina differed considerably in diet (Table 11). This may have reflected either short duration change in zooplankton diversity, abundance, or size, or different local plankton communities. There were nearly twenty times as many organisms per gut in the samples containing mostly Bosmina sp. as in those containing mainly Chydorus sphaericus (Table 11). Schooling larval white sucker at 14 mm do not possess the fully developed inferior mouth associated with feeding at the bottom, but are often found near the surface at the shore. The population of cladocerans exceeded cyclopoids by ca. eight-fold, and 18 mm larvae ate mostly Bosmina sp., which far outnumbered all species. Larvae and early juveniles from the marina samples apparently ate equal rations of Cyclops spp. and Chydorus

sphaericus, which differ considerably in size. The mean number of organisms in the diet increased with the size of the larvae. Youngest fish each took from 3 to 59 organisms, generally ignoring Cyclops spp. Larvae 20 mm in length each took an average of 174 organisms, and 32 mm larvae ate 468 organisms each, selecting in the process more large objects such as Cyclops spp.

Alosa pseudoharengus

Population Dynamics

Alewife were initially sampled on June 9; spawning thus occurred during the prior week, when the mean temperature was 21.0°C. Alewife led all species in abundance for four consecutive weeks, commencing June 9, when 4.9 mm TL. On July 6, they were 9.6 mm, and on August 10, they were 12.5 mm (Table 9). Larvae were slightly larger in open waters than in the littoral areas.

After peaking on June 9, density dropped by one-half the following week, then essentially maintained that level for the next two weeks, and successively dropped by one-half in the following weeks (Table 6). Abundance tended to increase uniformly from west to east along the transects. Possible reasons for absence of larval alewife in the lower part of the bay in early June are several: lack of appropriate spawning conditions, delayed hatching, advective transport to the northeast of planktonic forms, or dispersion by winds.

Larvae were last sampled at pelagic sites on August 10 and 24, or three to five weeks after they were last caught at shore stations. Hence, they probably moved offshore after nearshore areas had served as

nursery grounds. The findings of Keast (1980) were similar, i.e., only marginal occurrence of 10 to 12 mm alewife at inshore open water sites of Lake Opinicon, Ontario. Smaller (4.9 mm) larvae were highly concentrated at Richson Pt., however, and absent in nearby open waters. Early spawning concurrent with gizzard shad did not occur, since there was a span of four weeks between the first appearance on May 13 of shad and on June 9 of alewife. Nevertheless, newly hatched gizzard shad were found in pelagic waters until mid-July.

Catches in initial hauls at the shore and in the transects were significantly ($P<0.01$) greater than in replicates. Comparative initial to replicate catch at shore and transect differed by respective geometric mean factors of 1.27 and 1.22. The systematic difference observed between repeated passes along a transect is perplexing, but may reflect the fact that the initial haul was generally aided by the wind, which opposed the second.

Seining at 1 m resulted in more larvae ($P<0.05$) than at 0.5 m (GMF = 1.35). Catches also differed between the six shore sites ($P<0.01$). Offshore, alewife showed a distribution pattern unlike that of yellow perch. The outer transect (G-C; Fig. 1) had significantly ($P<0.01$) fewer larvae than did the inner (S-R), and the geometric mean ratio was 0.51. Also, the effect of transect portion was significant ($P<0.05$), with catches increasing on average from west to east.

Feeding

The guts of 121 larval and early juvenile alewife, ranging from 6.1 to 34.5 mm, were examined. These fish were comparable in number and size

to alewife studied by Norden (1968). All, except 32.7 mm larvae and juveniles caught at Sand Pt. on July 21, were from June 23 to 24 samples obtained at Cole Pt. and Richson Pt.

The smallest larvae ($\bar{x}$ = 7.2 mm) each had a mean of 1.6 organisms in their gut; five percent of the guts (N = 25) from Cole Pt. samples were empty. The main food items on June 23 were copepod nauplii and copepodites, comprising 77.5 percent, followed by Cyclops sp. (10 percent), and unidentified eggs (10 percent). At this time, the main cladocerans at Cole Pt. were Bosmina longirostris ($160 \times 10^3 m^{-3}$), Chydorus sphaericus ($9 \times 10^3 m^{-3}$), and Ceriodaphnia lacustris ($9 \times 10^3 m^{-3}$). In comparison, there was a total of $13 \times 10^3 m^{-3}$ cyclopoid copepodites and nauplii. Small larvae thus chose the smallest available plankters, i.e., nauplii.

Alewife 10 to 22 mm (N = 91) selected more cyclopoid copepodites and nauplii, which comprised as much as 99 percent of all the food eaten, even though cladocerans ($122 \times 10^3 m^{-3}$) outnumbered cyclopoids by a factor of 57. The number of items per tract increased from 5.3 in 10.3 mm fish to 57 in 22 mm larvae. Juveniles (32.7 mm) from Sand Pt. (N = 5) on July 21 were more diverse in food selection, varying from 12 percent adult Cyclops spp. to Bosmina spp. (75 percent), and Chydorus sphaericus (10 percent). Norden (1968) observed a similar diversity in feeding pattern, but of different crustacean species. The population of zooplankton in Muscote Bay had waned considerably by mid-July, but in spite of relatively few organisms on which to prey, there were 366 organisms per gut in juveniles.

The pattern of early feeding differs from the findings of Norden (1968), who noted that cladocerans were first eaten when alewife were 9.5 mm, and were chosen as food 28 percent of the time in 6 to 10 mm Lake Michigan larvae. In Muscote Bay, virtually no cladocerans were eaten until alewife were juvenile (32 mm), and copepods were eaten in increasing amounts as larvae grew. However, the diets of 30 to 40 mm fish in Lake Michigan and Muscote Bay were similar, as was the pattern of increased omnivorous feeding with size.

Dorosoma cepedianum

Population Dynamics

Gizzard shad was the fourth most-abundant species in Muscote Bay, being present from May 27 to July 27, inclusive, and in addition, on May 14 and September 9. They were generally abundant in all areas of the bay, but few in number at Sand Pt. and Barnhart Island (Fig. 1; Table 6).

Based on its early appearance at 12.3°C in transect waters on May 14, gizzard shad probably spawned in warm, shallow water during the previous week, when the mean water temperature was 15.7°C. By the end of May, abundance rose to a peak (Table 6), and at 3.4 mm, larvae were planktonic. However, there was no immediate evidence of the effect of winds on distribution patterns. On June 15, there were 252 larvae $100\ m^{-3}$ at Gravelly Pt., possibly influenced by high winds (Table 2). Gizzard shad were last sampled on July 20 at the shore and in open water on July 27, when their mean size was 22.7 mm (Table 9). Unscheduled sampling at Sawguin Island on September 26 resulted in a catch of 35 juveniles, which ranged from 62 to 94 mm ($\bar{x} = 70.6 \pm 8.1$ mm); temperature

in the bay at that time was 15.0°C. Only three specimens were netted on four sampling dates in May and June, 1982. The sharp contrast in density of shad in successive years serves to emphasize the importance of extensive sampling more than for only a single year.

Replicate catches at the shore and in transects were generally less ($P<0.01$) than in initial hauls, and the respective geometric mean factors for shore and transect samples were 1.35 and 1.39. Like most species, gizzard shad seemed to avoid the edge of the shore, as a significant ($P<0.05$) catch difference existed between the 1 and 0.5 m depths (GMF = 2.09). There were also significant catch differences ($P<0.01$) between the various shore sites (Table 8). On the other hand, the density of shad was essentially the same in both transects, and did not differ along the length of the transects.

There were striking differences in mean size of larvae at various locales on the same date. For example, the mean length of shad on July 6 ranged from 4.3 mm at G-C to 17.1 mm at Richson Pt. This indicates habitat preference of larvae differing in size. First hatch was estimated to have occurred during the second week of May and the latest hatch during the second week of July. These events reflect the extended spawning and/or hatching range of the species in specific areas.

The findings of numerous studies of gizzard shad are varied, and do not always agree, often because of incomparable hydrological and limnological characteristics. Further, abundance estimates are related not only to sheer presence of a species, but are strongly related to sampling methods and strategy. Lam (1977) found an obvious concentration in bays and enclosed locations, with low density in open water stations

of the Bay of Quinte. In contrast, Storck et al. (1978) found larvae concentrated more in the limnetic habitat. Snyder (1978) found them most abundant and well distributed in turbid water. Although in Muscote Bay they initially appeared mainly in open surface waters, gizzard shad were later usually found in nearshore areas, where they were most abundant at all sizes, but did not favour turbid water. Shad in Muscote Bay exemplified the spatial and temporal patchy nature of some species of larval fish in the planktonic phase, when they are largely at the mercy of wind effects, and currents.

Labidesthes sicculus

Population Dynamics

Judging by the summary of Goodyear et al. (1982) of the early life history of brook silversides, spawning probably occurred at least two weeks prior to first appearance on June 9 of larvae (mean length: 5.0 mm); peak abundance occurred on June 23 (Table 6). Winds (calm to light at peak catch) did not appear to affect their distribution. A final catch of 29 juveniles (57.2 $\pm$ 7.5 mm) occurred on October 14 at Sand Pt. The extremely rapid growth of this semiparous species was noted by Nelson (1968). Mean size data for the regular sampling period are given in Table 9.

Although not the most abundant species, brook silversides were present on more sampling occasions than any other, and was one of six species present at all sampling locations. During the third week of July, it led in terms of abundance, and was third most-abundant during late June (Table 6). Notably, the brook silversides was the first

young-of-the-year species caught during beach seining in April, the last sampled as larvae in August, and finally, in September, the last young-of-the-year caught during regular sampling. Brook silversides were usually more abundant in samples in littoral than pelagic waters throughout the sampling period. In contrast, no larvae were caught in 1982.

Feeding

The main food of 80 young brook silversides (5 to 35 mm)(Table 12), was Cyclops spp. and cladocerans. Bosmina spp. were eaten to a lesser extent, and Daphnia spp were included when the fish were juveniles (34.8 mm). Larvae of 5.6 to 8.8 mm selected Cyclops spp, despite a much greater presence of Bosmina spp., but larger fish essentially consumed food items in proportion to relative abundance at each of the sampled locations.

Brook silversides were not generally found in greatest abundance at the location of highest zooplankton standing crop. For instance, on June 22, fish were in greatest abundance at Sand Pt., Richson Pt., and Barnhart Island, while zooplankton were most abundant at Cole Pt. and Richson Pt. Although the preferred food of these larvae (26.8 mm) was Cyclops spp., (Table 12), cladocerans, especially Chydorus sphaericus, and Bosmina spp., outnumbered by an order of magnitude all cyclopoids.

Morone americana

Population Dynamics

White perch were found at six sampling stations, but mainly in the

open water, and were the third most abundant in the bay during the first three weeks in June, and in the first week of July. They appeared initially on May 11 in transect waters (S-R) at 12.3°C, and were 3.7 mm. White perch abundance peaked on June 1 in transect waters (G-C)(Fig. 1), and on June 9 at Gravelly Pt (Table 8). Water temperature at this time was 19.6°C. They were one of the smallest larval fish caught in Muscote Bay; mean size on June 2 varied from 2.1 mm at Gravelly Pt. to 7.5 mm at Cole Point. Mean size on August 10 was 24.4 mm, and 69.8 mm (N = 12) at last capture on September 26. Relatively few larvae were caught in open water in 1982; only a single specimen was netted at the shore.

White perch were initially caught as protolarvae in open waters of the bay. High winds (20 to 30 km/h) from the southwest were prevalent during peak abundance and may have effected transport of larvae to the eastern shore of Muscote Bay. According to the survey of Lam (1977), winds were considered to have affected the distribution of this species, one of the five most abundant in the Bay of Quinte. In Muscote Bay, the ratio in 1981 of the catch of yellow perch to white perch was 25:1, whereas in the Bay of Quinte in 1974 it was 4:1 (Lam 1977). Whatever the reasons for recent changes in the fish community of the Bay of Quinte (Christie, 1968; Sheri and Power, 1969; Hurley and Christie, 1977), shallow, warm bays apparently favour spawning and possibly successful production of yellow perch, whereas deeper, cooler waters favour white perch. Lam (1977) found more white perch at 3 m than at the surface, suggesting depth preference. The shallow water of Muscote Bay did not appear to deter white perch from spawning there, nor from use of it as a nursery.

Feeding

Larval white perch (N = 40) from early to mid-June were examined for gut contents. All fish were mesolarvae, and were caught at offshore locations, where abundance was generally highest. Smallest larvae (5.2 mm) ate cyclopoids exclusively, had a mean value of 19 organisms in the gut, and apparently ignored cladocerans, which comprised 56 percent of the total zooplankton. As larvae progressively grew to 6.0, 6.7, and 7.9 mm, mean items per tract were 2.9, 6.3, and 7.5, respectively, and the proportion of the cyclopoids eaten by the largest fish was half that consumed by smaller ones. Bosmina spp. formed 45 percent of the diet of the 7.9 mm larvae. As larvae grew, their diet changed from almost exclusively cyclopoid nauplii and copepodites to one which also included an equal share of Bosmina spp. All guts contained various amounts of unidentifiable organic matter, and none were empty.

Notemigonus crysoleucas

Population Dynamics

Golden shiner were first caught (mean size: 4.3 mm) in beach seines at Richson Pt. (Fig. 1) on May 13, when water temperature was 14.3°C (Table 2). General appearance in the bay was from June 1 to July 6, but Barnhart Island appeared to be a favoured site. No golden shiner were caught in G-C transect waters and only a few were taken in the S-R area. This species was caught August 24, when the mean size was 50.3 mm (N = 53), and on October 15 in seines (mean TL = 49.0 mm; N = 7). Golden shiner were notably episodical at most stations, appearing at shore stations on one to three sampling occasions, but were not widely

dispersed. During May and June, 1982, 26 larvae were caught at the shore and three in open water. Pre hatch water temperature during the first week of May was 15.7°C, which is considerably lower than the spawning temperature reported in Scott and Crossman (1973), or by Faber (1980). Nearshore shallows provide suitable cells for spawning and incubation due to temperatures well above the mean temperature of the bay, and probably account for its relatively early appearance.

Lepomis gibbosus

Population Dynamics

Pumpkinseed were selective of habitat, largely favouring Barnhart Island and Sawguin Island (Fig. 1), where they first occurred on June 1 (mean size: 5.4 mm; Table 9). First instance of spawning was probably at 19 to 20°C. Peak abundance occurred at Sawguin Island on June 22, and Barnhart Island on July 9, when water temperature was 28.0°C. This was one of the few species present at all sampling sites. Pumpkinseed continued to appear in pelagic areas a week or so later than at the shore; peak abundance on July 31 in open water was never more than 12 larvae 100 m^{-3}. They were last caught as larvae at Sawguin Island on September 7, when 7.0 mm, but of all species, appeared to be the most readily seined as juveniles. Size in mid-October, 1981, was 48.5 mm, considerably larger than those sampled (37.1 mm) a year later in the same area and at the same time.

Pelagic populations of "sunfish" (pumpkinseed and bluegill, Lepomis macrochirus) sampled in western Lake Erie (Cooper et al., 1981) were relatively contracted in appearance to three to four weeks, whereas

Amundrud et al. (1974) caught these species in Lake Opinicon, Ontario, over six weeks. Lam (1977) caught more than 300 "sunfish" in pelagic hauls in the Bay of Quinte during July. In comparison, the present study indicated a much more protracted appearance, i.e., 11 weeks in the pelagic areas, and 14 weeks in shore areas of Muscote Bay.

Species in Low Abundance

Lake whitefish, Coregonus clupeaformis, are historically of great importance to the Great Lakes fishery, but because of degradation of reproductive environment, explosion of exotic species, overfishing, and sea lamprey predation (Hurley and Christie, 1977), have been scarce since the 1960's. In 1981, there were 75 whitefish larvae sampled in Muscote Bay. A single protolarva (8.3 mm) was caught in 12.4°C surface water at S-R (Fig. 1) on April 30, four more at Barnhart Island (19.7 mm), and ten larvae at Gravelly Pt. (22.5 mm). According to Goodyear et al. (1982), lake whitefish spawn on hard, clean substrates. Barnhart Island and Sawguin Island were thus not suitable areas for spawning, but provide shelter for protolarvae, and may be suitable as temporary nurseries. No further catches were made after May 7, when mean water temperature in the bay was 15.7°C, and larvae were ca. 26 mm. Four larvae were caught in 1982, the first two (19.6 mm) of which were netted in open water on May 12, and the others at Cole Pt. on June 2.

It is likely whitefish spawn in selected areas of Muscote Bay, and the young emigrate in late April and early May. The northeast boundary (Big Island) of Muscote Bay, was in fact formerly a known site for schooling whitefish larvae (Hart, 1930).

An insight into some feeding habits of larval whitefish was possible when a sample of 25 whitefish larvae, caught on April 22, 1981, at the shoreline of Hay Bay (Lam, 1977), and 10 larvae each from Richson Pt. and Sand Pt. on May 7, 1981, were examined for gut contents. The mean number of organisms per tract increased from 59 in 16.4 mm larvae to 133 at 23.0 mm, and 234 in 26.0 mm larvae. The Hay Bay larvae consumed mostly (94 percent) cyclopoids, with a trace of Bosmina spp., Daphnia spp., Chydorus sphaericus, and fish eggs (possibly Lota lota). On May 7, Richson Pt. larvae (23.0 mm) favoured Cyclops spp. (63 percent), Bosmina spp. (23 percent), and Chydorus sphaericus (10 percent). On the same date, feeding at Sand Pt. was confined mostly to Cyclops spp. (91 percent of food items), with a few additional Daphnia spp. and Bosmina spp.

After 1960, there were few stream runs of smelt in the Bay of Quinte, with few suitable habitats in the area (Christie, 1974). During sampling in 1974, Lam (1977) caught 2,100 smelt larvae, most of which were in the lower bay (adjacent to Lake Ontario), in mid-May and the first week in June. In contrast, only three smelt were caught in Muscote Bay.

Spring and summer-long sampling by Lam (1977) resulted in a catch in 1974 of four larval walleye, Stizostedion vitreum. Similarly, our intensive shore and open-water sampling in Muscote Bay resulted in a catch of one walleye. The single larva (9.0 mm) was caught in the process of devouring a yellow perch (ca. 6 mm), and was thus the sole evidence of active piscivory by all larval and juvenile fish. On May 27, 1982, two larvae were caught near Cole Pt., and one on June 9 at the shore. There is little doubt that Muscote Bay is a marginal spawning area for walleye, although adults are frequently caught there by sport fishermen.

Several cyprinid species, e.g., spottail shiner, Notropis hudsonius, carp, Cyprinus carpio, and spotfin shiner, N. spilopterus, were caught almost solely in shallow, protected areas. Juvenile bass, never abundant, were seined in the company of numerous species in shallow, weedy areas. Largemouth bass, Micropterus salmoides, were 58 mm in late August, and ca. 65 mm in mid-October; smallmouth bass, M. dolomieui, were 69 mm in late September. Rock bass, Ambloplites rupestris, were present throughout the autumn in weedy, rocky habitats. In late August, they were 37 mm in length and attained 46 mm by early November. Young brown bullhead, Ictalurus nebulosus, (54.2 $\pm$ 4.4 mm; N = 14), were caught on October 15 in reeds at Sawguin Island.

A number of uncommon species were seined at a marina. Single catches were made on August 25, 1982, of a juvenile black bullhead, Ictalurus melas, an adult brook stickleback, Culea inconstans, and on October 14, 1982, of a juvenile tadpole madtom, Noturus gyrinus, and a juvenile fallfish, Semotilus corporalis.

Adult eastern central mudminnow, Umbra limi, bowfin, Amia calva, northern pike, Esox lucius, channel catfish, Ictalurus punctatus, longnose gar, Lepisosteus osseus, and mottled sculpin, Cottus bairdi, were observed and occasionally sampled at several shore sites, but the young were never found.

Summary and Conclusions

Although small in area and volume, Muscote Bay has a large, diverse population of larval fish. It serves as a nursery both for resident and transient species.

1. There were 48 x 10^3 shore and 20 x 10^3 pelagic larval fish caught; 26 (including an "unknown") species were present, 24 of which were sampled at shore stations, and 14 in open waters.
2. Total catch of fish tended to be larger near the shore (especially the west) than in the centre of the transect. Barnhart Island and Sand Pt. had the respective highest and lowest absolute abundance of larval fish.
3. Replicate catches of all species, both at the shore and in transects, were usually smaller than initial catches. Differences in catch may be explained, in part, on the basis of depletion with repeated sampling, and possibly avoidance due to perturbation.
4. Density of larval fish was generally less at 0.5 m than at the 1 m stratum, suggesting avoidance of the shoreline, or surf, zone.
5. The highest diversity occurred during early to mid-June; lowest diversity was in early May and early August. Sand Pt. and the open waters had the lowest diversity; Cole Pt., Gravelly Pt., and Sawguin Island had the highest diversity.
6. Five species, yellow perch, brook silversides, pumpkinseed, alewife, and gizzard shad, were present at all sites. Yellow perch was the most abundant, widespread, and persistent species; white sucker the most concentrated, localized, and ephemeral.
7. Littoral species were brook silversides, minnows, sunfish, and basses; pelagic species were alewife and white perch. Yellow perch and gizzard shad were wide-ranging in distribution, and during growth, alternately chose littoral and open waters.

8. Yellow perch were found as larvae mostly inshore; they dispersed with increasing size, became transient when juvenile, and probably moved to colder waters in mid to late summer. They took shelter in protected areas prior to winter. Spawning areas in Muscote Bay for yellow perch were few, yet, two unlikely locations, Gravelly Pt. and Barnhart Island, were such sites. The spawning period was short (two to three weeks), occurring at ca. 13 to 16°C. Coincident peak abundance occurred of cladocerans and yellow perch larvae during the sensitive period of early life; these crustaceans were the main food of larval perch.
9. White sucker left the streams for the bay during mid-spring, when they were 13 to 18 mm. They were found as larvae at marinas, and along shaded, sandy beaches, but juveniles were not caught. It was assumed they emigrated from the shallow bay during late spring, and were thus transient.
10. Alewife had a spawning period of about three weeks in water of about 21 to 23°C. As larvae, they were found mostly near shore; later, as juveniles, they moved to open waters, but remained in the bay.
11. The spawning period of gizzard shad was estimated to be two months, at 15 to 23°C. They were mostly found as larvae at the shore, but as juveniles, tended to move into open waters. This species was, however, one of the few caught at the shore as juvenile.
12. Spawning period of white perch was protracted, extending from early May to late June (12 to 22°C). As larvae, they were found mostly in open waters, but moved inshore as the water in the bay warmed.

13. Mean water temperature in the bay exceeded 21°C for at least six consecutive weeks, which enhance shorter hatch periods and rapid growth for many species.
14. Routine larval fish sampling is virtually ineffective for the capture of juveniles, which avoid samplers. Where possible, shore seining should be utilized for regular ecological studies of larval fish.

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TABLE 1: Regular sampling dates for larval fish, Muscote Bay, 1981.

Sampling Date	Cole Pt.	Gravelly Pt.	Richson Pt.	Sand Pt.	Barnhart Island	Sawguin Island	G-C	S-R
April 30/May 1		x			x	x	x	x
May 6-7	x	x	x	x	x	x	x	x
May 13-14	x	x	x	x	x	x	x	x
May 20-21	x	x	x	x	x	x	x	x
May 25-27	x	x	x	x	x	x	x	
June 1-4	x	x	x	x	x	x	x	x
June 8-11	x	x	x	x	x	x	x	x
June 15-18	x	x	x	x	x	x	x	x
June 22-25	x	x	x	x	x	x	x	x
July 2							x	x
July 6-9	x	x	x	x	x	x	x	x
July 20-22	x	x	x	x	x	x	x	
July 27							x	x
August 6-7							x	x
August 10-13							x	x
August 17-20							x	x
August 24-27	x	x	x	x	x	x	x	x
August 31							x	
September 9	x	x	x	x	x	x		

TABLE 2: Climatological data, Muscote Bay, 1981, during larval fishing.

Sampling Date 1981	Mean Water Temperature (C)	Temperature Range and Sampling Site	Wind (km/h)	Cloud cover (%)
April 30 to May 1	13.6	12.4 (SP)-18.3 (GP)	SW 20	40-70
May 6-7	15.7	12.2 (SP)-17.6 (BI)	SW 10	10-3
May 13-14	12.3	10.7 (SI)-14.3 (RP)	SW 10	50-100
May 20-21	17.1	14.7 (G-C)-20.8 (GP)	SW 15	20-80
May 26-27	19.9	18.5 (RP)-23.0 (GP)	SW 5	40-100
June 2-3	21.0	19.6 (G-C)-22.8 (SP)	SW 0-20	0-70
June 9-10	20.7	19.3 (CP)-22.0 (SI)	SSW 0-30	30-100
June 16-17	23.2	20.0 (G-C)-27.5 (GP)	SW 15-30	0-50
June 23-24	21.5	19.8 (SI)-23.5 (GP)	W 10	10-100
July 7-8	27.1	24.5 (CP)-28.0 (BI)	SW 10	0-20
July 21-22	24.2	22.0 (S-R)-26.3 (RP)	NW 12	10-90
August 5	23.4	22.3 (CP)-24.0 (RP)	calm	
September 9	17.9	16.8 (GP)-19.2 (SI)	NW 15	60-100
September 25	15.0	SP	W 7	100
October 16	10.8	SP		

TABLE 3: Zooplankton checklist, and total abundance rank (exclusive of copepodites and nauplii) of main species in Muscote Bay, 1981.

Species	Abundance Rank	Sampling Location							
		CP	GP	RP	SP	BI	SI	G-C	S-R
Bosmina longirostris	1	x	x	x	x	x	x	x	x
Eubosmina coregoni	2	x	x	x	x	x	x	x	x
Daphnia retrocurva	4	x	x	x	x	x	x	x	x
Daphnia galeata mendotae	5	x	x	x	x	x	x	x	x
Daphnia pulex					x				
Daphnia catawba			x						
Ceriodaphnia lacustris	6	x	x	x	x	x	x	x	x
Ceriodaphnia sp.							x		
Chydorus sphaericus	3	x	x	x	x	x	x	x	x
Diaphanosoma birgei		x	x	x	x	x	x	x	x
Diaphanosoma brachyurum	9						x		x
Holopedium gibberum			x						
Alona quadrangularis		x							
Alona guttata		x	x	x	x	x	x	x	x
Alona affinis			x	x		x	x		
Simocephalus serrulatus									x
Eurycercus lamellatus							x		
Sida crystallina					x	x	x		
Pleuroxus denticulatus							x	x	
Pleuroxus procurvus							x		
Camptocercus rectirostris							x		
Acroperus harpae							x		
Leydigia quadrangularis			x				x		x
Scapholeberis kingi				x	x		x		
Polyphemus pediculus							x		
Leptodora kindtii		x	x		x	x	x	x	x
Cyclops bicuspidatus thomasi			x		x				x
Cyclops vernalis	8	x	x	x	x	x	x	x	x
Tropocyclops prasinus mexicanum	10	x	x	x	x	x	x	x	x
Mesocyclops edax		x					x	x	x
Eucyclops agilis			x	x			x		x
Ergasilus sp.									x
Cyclopoid copepodites		x	x	x	x	x	x	x	x
Cyclopoid nauplii		x	x	x	x	x	x	x	x
Diaptomus oregonensis		x				x			x
Diaptomus siciloides		x							
Eurytemora affinis		x	x	x	x	x	x	x	x
Calanoid copepodites		x	x	x	x	x	x	x	x
Calanoid nauplii		x	x	x	x	x	x	x	x
Harpacticoid copepodites						x			
Ostracod sp.	7	x	x	x	x	x	x	x	x

TABLE 4: Mean abundance (no. x 10^3 m^{-3}) of main groups of zooplankton, May to September, 1981, in Muscote Bay.

GROUP	SAMPLING DATE (day/month)								
	26/5	2/6	9/6	16/6	23/6	7/7	21/7	25/8	9/9
Cladocera	221	249	75	45	66	331	44	8	34
Cyclopoida	35	63	64	49	17	39	7	8	12
Calanoida	0.5	4	2	1	0.9	1	0.1	0.1	0.4
Ostracoda	0.1	5	3	1	0.1	0.3	0.1	0.1	0.1

TABLE 5: Species checklist, by week, of larval fish caught in Muscote Bay, 1981.

SPECIES LIST	SAMPLING DATE								
	30/4	6/5	13/5	20/5	26/5	2/6	9/6	16/6	23/7
Alosa pseudoharengus							x	x	x
Dorosoma cepedianum			x		x	x	x	x	x
Coregonus clupeaformis	x	x							
Osmerus mordax						x			
Carpiodes cyprinus								x	
Catostomus commersoni	x		x	x	x	x	x	x	
Notemigonus crysoleucas			x				x	x	x
Notropis atherinoides						x			
Notropis hudsonius								x	x
Notropis spilopterus		x		x		x		x	
Cyprinus carpio					x	x	x	x	x
Notropis chrysocephalus					x	x	x	x	
Notropis sp.									
Percopsis omiscomaycus						x			
Morone americana			x	x	x	x	x	x	x
Lepomis gibbosus						x	x	x	x
Micropterus dolomieui							x		
Micropterus salmoides									
Pomoxis nigromaculatus									
Perca flavescens	x	x	x	x	x	x	x	x	x
Stizostedion vitreum			x						
Etheostoma nigrum				x	x	x	x	x	x
Percina caprodes							x		
Labidesthes sicculus			x		x		x	x	x
Aplodinotus grunniens						x			
Indet.				x	x	x			x

Table 5 (cont'd)

(day/month)										
2/7	7/7	13/7	21/7	27/7	3/8	10/8	17/8	24/8	31/8	9/9
x	x	x	x	x	x	x		x		
x	x	x	x	x						x
	x									
			x					x		
								x		
	x									x
	x									
	x									
	x									
x	x					x				
x	x	x	x	x	x			x		
			x					x		x
	x		x							
		x								
	x							x		
	x		x							
x	x	x	x	x			x	x		x
		x								

TABLE 6: Weekly mean abundance (no. x 100 m^{-3}) of larval fish in Muscote Bay, 1981.

SPECIES	SAMPLING DATE								
	30/4	6/5	13/5	20/5	26/5	2/6	9/6	16/6	23/6
Alosa pseudoharengus							60.3	30.0	37.8
Dorosoma cepedianum			0.0		58.9	23.9	39.7	28.3	7.3
Coregonus clupeaformis	3.4	6.9							
Osmerus mordax						0.3			
Carpiodes cyprinus								0.1	
Catostomus commersoni	0.3		301	16.5	4556	218	0.9	0.5	
Notemigonus crysoleucas			0.4			9.4	0.1	0.6	35.4
Notropis atherinoides								1.5	11.9
Notropis hudsonius		1.3		1.6		1.7		0.1	
Notropis spilopterus					1.6	0.9	2.9	0.3	4.8
Cyprinus carpio					0.4	0.1	0.3	0.6	
Notropis chrysocephalus									
Notropis sp.						0.0			
Percopsis omiscomaycus			0.0	0.0	1.7	28.3	20.5	5.9	3.1
Morone americana						1.3	1.3	0.2	11.2
Lepomis gibbosus							0.1		
Micropterus dolomieui									
Micropterus salmoides									
Pomoxis nigromaculatus									
Perca flavescens	100	191	85.6	1042	699	165	10.0	1.2	2.8
Stizostedion vitreum			0.1						
Etheostoma nigrum				0.3	0.4	0.3	0.3	0.4	0.1
Percina caprodes							0.1		
Labidesthes sicculus			0.2		0.6		0.2	0.9	28.0
Aplodinotus grunniens						0.1			
Indet.				0.1	0.2	0.1			0.1

Table 6 (cont'd)

(Day/Month)

2/7	7/7	13/7	21/7	27/7	3/8	10/8	17/8	24/8	31/8	9/9
28.7	9.8	4.8	0.5	0.8	0.0	0.1		0.0		
19.1	2.8	15.8	0.4	0.6						0.3
	0.1							0.1		
			0.2							
								0.1		0.4
	0.2									
	0.1									
	0.1									
	0.1									
2.5	0.5					0.1				
0.8	13.0	7.5	4.2	1.0	0.0			0.1		0.3
			0.7					0.1		
	2.1		0.5							
		0.1								
	0.6							0.2		
	0.1		0.5							
0.4	7.5	0.1	5.0	0.1			0.1	0.3		0.1
		0.1								

TABLE 7: Presence, peak abundance, and numerical rank of main species of young fish in Muscote Bay, April to September, 1981.

Species	Presence	Peak Abundance no.x 100 m^{-3}	Occurrence	Numerical Rank
Catostomus commersoni	late April to mid-May	4556.3	late May (episodal)	2
Perca flavescens*	late April to mid-May	1042.0	mid-May	1
Alosa pseudoharengus	early June to late August	60.3	early June	3
Dorosoma cepedianum*	early May to September	58.9	late May	4
Notemigonus crysoleucas	mid-June to early July	35.4	late June	8
Morone americana*	mid-May to mid-August	28.3	early June	5
Labidesthes sicculus	mid-May to mid-September	28.0	late June	7
Lepomis gibbosus	early June to mid-September	11.2	late June	6
Notropis hudsonius	mid/late June	11.0	late June (episodal)	9
Cyprinus carpio	late May to early July	4.8	late June	10

* Species appearing throughout sampling period

TABLE 8: Summary of results of statistical tests, 1981.

Shore Data:

	Replicates - t (df)		Depths - t (df)		Sites - F (df)	
Total Catch	10.03 (155)	***	4.84 (155)	***	4.02 (5,255)	**
Perch	4.96 (131)	***	6.93 (131)	***	4.97 (5,215)	***
Alewife	3.17 (59)	**	2.81 (59)	**	8.48 (5,95)	***
Gizzard Shad	4.10 (95)	***	3.29 (95)	**	5.78 (5,155)	***

Transect Data:

	Replicates - t (df)		Portion - F (df)		Sites - t (df)	
Total Catch	4.69 (179)	***	4.60 (5,275)	***	-0.56 (179)	ns
Perch	1.48 (47)	ns	2.28 (5,95)	ns	-2.13 (71)	*
Alewife	3.35 (131)	**	5.70 (5,215)	***	5.18 (131)	***
Gizzard Shad	3.93 (107)	***	1.79 (5,195)	ns	-0.79 (119)	ns

ns - not significant
* - P<0.05
** - P<0.01
*** - P<0.001

TABLE 9: Mean total length (mm) of larval fish during sampling periods in Muscote Bay, 1981.

SPECIES	SAMPLING DATE								
	30/4	6/5	13/5	20/5	26/5	2/6	9/6	16/6	23/6
Alosa pseudoharengus							4.9	7.2	5.8
Dorosoma cepedianum					3.6	4.6	6.7	10.0	13.3
Coregonus clupeaformis	20.8	24.5							
Osmerus mordax						5.2			
Carpiodes cyprinus								26.6	
Catostomus commersoni	13.8		14.0	13.7	17.4	20.1	24.2		
Notemigonus crysoleucas			4.3			7.9		11.8	17.1
Notropis atherinoides									
Notropis hudsonius								16.5	21.1
Notropis spilopterus		26.6		5.9		7.1		12.8	
Cyprinus carpio					5.3	4.5	7.1		5.6
Notropis chrysocephalus					7.1		8.2	10.4	
Notropis sp.									
Percopsis omiscomaycus						5.6			
Morone americana			3.7	3.8	3.1	6.6	5.7	7.7	7.4
Lepomis gibbosus						5.1	5.6	5.9	5.8
Micropterus dolomieui							29.9		
Micropterus salmoides									
Pomoxis nigromaculatus									
Perca flavescens	6.1	7.2	9.1	10.3	12.9	14.1	20.2	26.4	29.9
Stizostedion vitreum			9.1						
Etheostoma nigrum				5.8	7.8	10.0	16.4	22.6	
Percina caprodes							22.4		
Labidesthes sicculus			39.5		7.6		5.0	5.8	5.9
Aplodinotus grunniens						4.4			

Table 9 (cont'd)

(Day/Month)								
2/7	7/7	13/7	21/7	27/7	3/8	10/8	17/8	24/8
7.2	9.5	13.4	18.7	16.8	19.9	12.6		17.8
4.3	8.3	14.0	23.4	22.7				
								50.3
			44.5					
								14.4 18.3
	5.7							
	40.5							
5.1	8.1					24.4		
6.0	5.6	6.0	8.0	5.4	7.3			48.0
			44.9					60.0
	31.8		45.4					
		4.2						
	39.5							54.8
			37.9					
6.2	10.1	8.3	12.4	27.2			35.5	31.7 55.6
		5.3						

TABLE 10: Food selection by larval Perca flavescens during May 14 (upper figures), May 20 (middle), and June 2 (lower figures), at sites in Muscote Bay, 1981. Lengths in millimeters; tr = trace (<5%); dash (-) = absence.

	SAMPLING LOCATION							
	BI	SI	SP	GP	CP	RP	S-R	G-C
No. of guts	25	4	24	25	25	-	25	25
	27	3	26	25	25	7	26	25
	-	25	15	5	25	25	15	13
Mean TL	10.0	9.5	8.8	8.7	8.8	-	9.2	8.7
	11.6	9.8	9.6	10.4	10.5	10.8	10.5	10.2
		15.5	18.2	15.1	18.9	18.5	13.9	12.5
Food items per tract	7.8	1.5	6.5	9.0	4.5	-	12.0	18.4
	18.3	5.7	12.0	13.4	7.7	15.1	20.4	14.3
		15.9	25.1	47.6	71.7	54.6	37.1	37.2
% Cyclops	92	67	91	96	95	-	96	96
	16	65	92	97	88	95	88	86
	-	tr	70	6	tr	35	25	93
% Bosmina	7	33	tr	tr	5	-	tr	tr
	79	35	tr	tr	10	tr	tr	tr
	-	85	16	30	80	58	64	tr
% Daphnia	tr	tr	tr	tr	tr	-	tr	7
	tr	tr	tr	tr	tr	tr	tr	tr
	-	6	5	63	14	5	7	tr

TABLE 11: Percentage of main food items consumed by young Catostomus commersoni in and near Muscote Bay, 1981. tr = trace (<5%).

SAMPLING LOCATION	No. of Fish	Mean TL (± SD)	MAIN FOOD CONSUMED (%)		
			Cyclops sp.	Bosmina sp.	Chydorus sphaericus
Barnhart Island	25	13.3 ± 0.6	19	29	24
Marina	25	14.1 ± 0.7	6	27	54
Marina	25	14.1 ± 0.6	tr	96	0
Barnhart* Island	25	18.0 ± 0.9	0	92	8
Barnhart* Island	25	17.6 ± 0.7	tr	88	7
Cole Pt.	25	20.0 ± 1.0	64	26	6
Marina	7	32.1 ± 2.2	49	tr	44

*Replicates

TABLE 12: Percentage of main food items consumed by Labidesthes sicculus in Muscote Bay, 1981. tr = trace (<5%).

SAMPLING LOCATION	No. of Fish	Mean TL (± SD)	FOOD CONSUMED (%)			
			Cyclops sp.	Bosmina sp	Daphnia sp.	Chydorus sphaericus
Richson Pt. & Barnhart Is.	25	5.6 ± 0.5	56	19	0	tr
Sand Pt.	10	8.8 ± 1.1	68	0	0	25
Cole Pt.	15	10.4 ± 1.0	28	44	0	5
Sand Pt. & Richson Pt.	10	16.2 ± 1.1	35	14	tr	51
Sand Pt.	5	22.1 ± 1.0	32	35	8	23
Sawguin Is.	10	26.8 ± 1.9	27	17	tr	25
Sand Pt.	5	34.8 ± 1.8	7	28	19	40

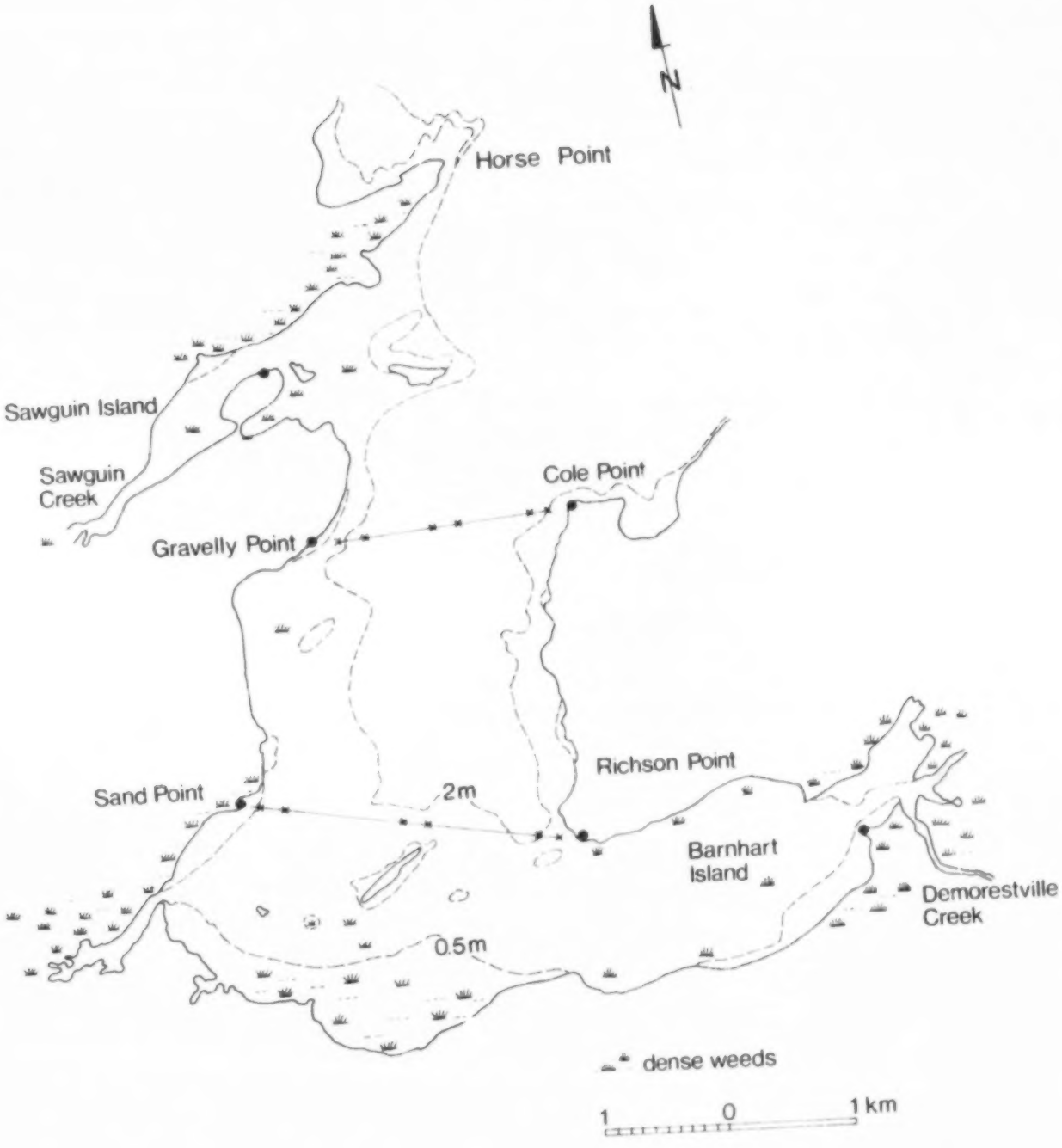

Figure 1. Map of Muscote Bay, showing sampling locations.

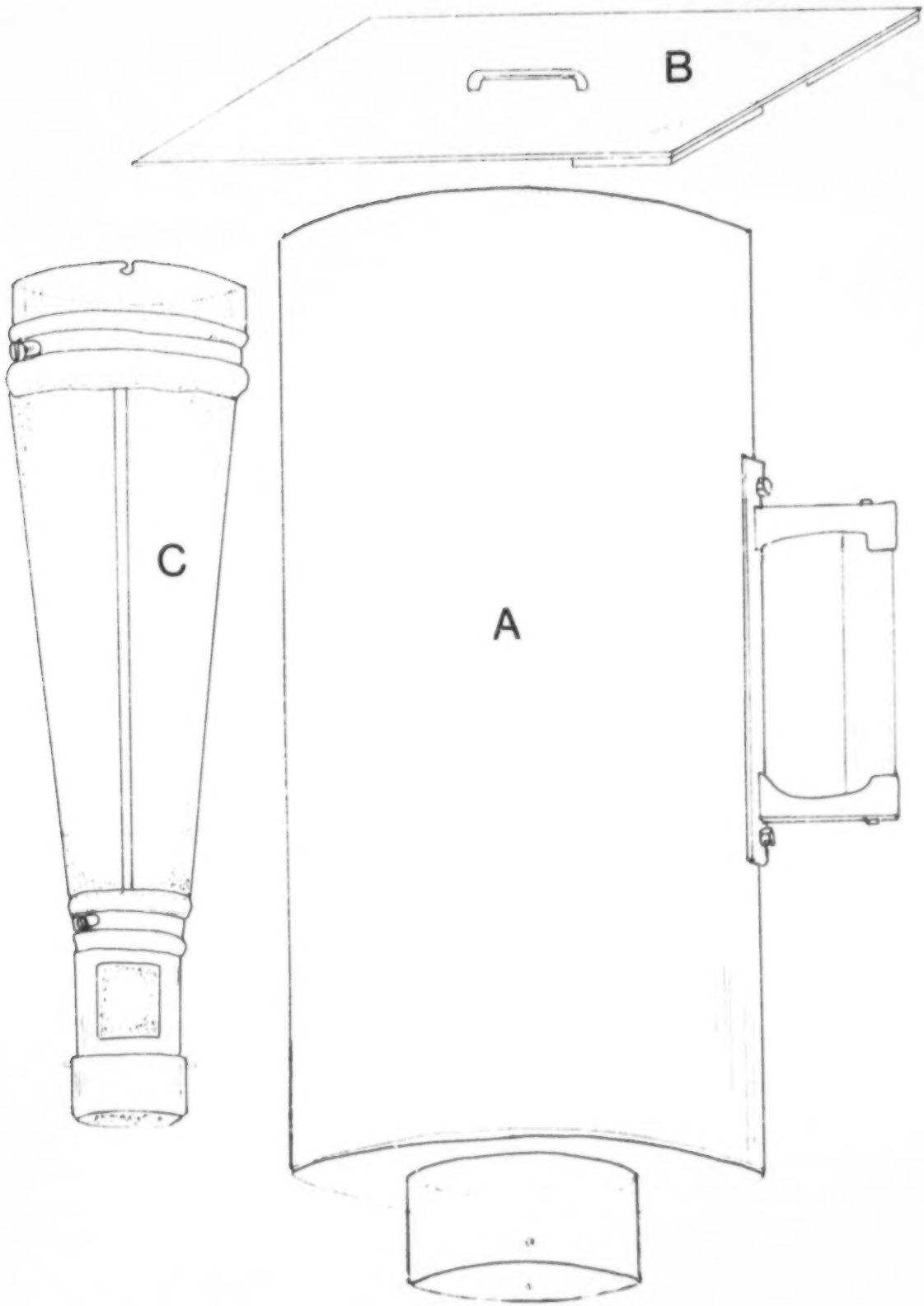

Figure 2. JEM sampler. (A) 13-litre plastic cylinder with handle; (B) top slip cover; (C) 0.C73-mm conical filter and removable bottom cup.

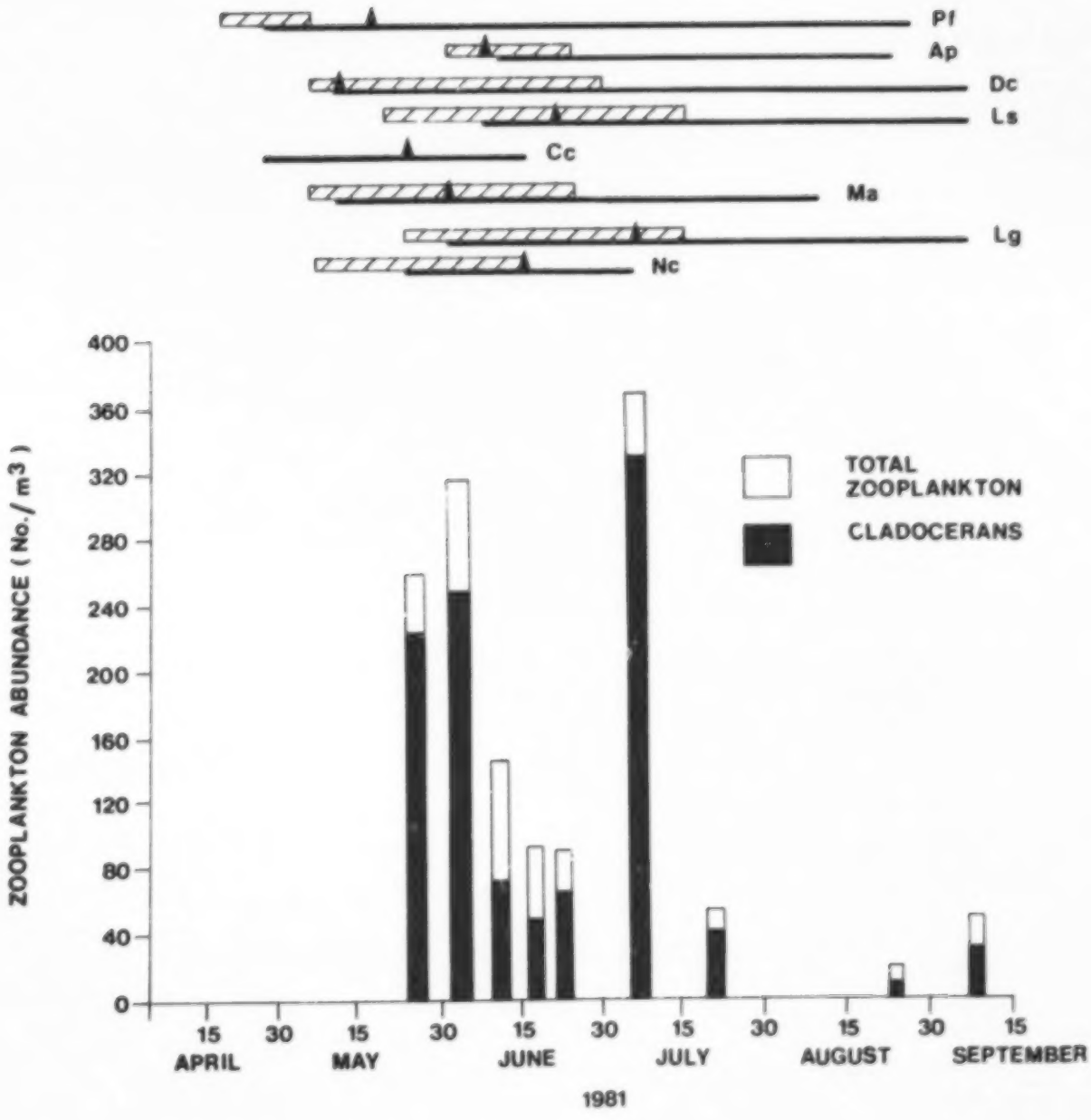

Figure 3. Abundance during April to September, 1981, of total zooplankton and cladocerans, larval fish occurrence (solid line), occasion of peak abundance (▲), and estimated spawning period (hatched bar) of Pf: Perca flavescens, Ap: Alosa pseudoharengus, Dc: Dorosoma cepedianum, Ls: Labidesthes sicculus, Cc: Catostomus commersoni, Ma: Morone americana, Lg: Lepomis gibbosus, and Nc: Notemigonus crysoleucas.

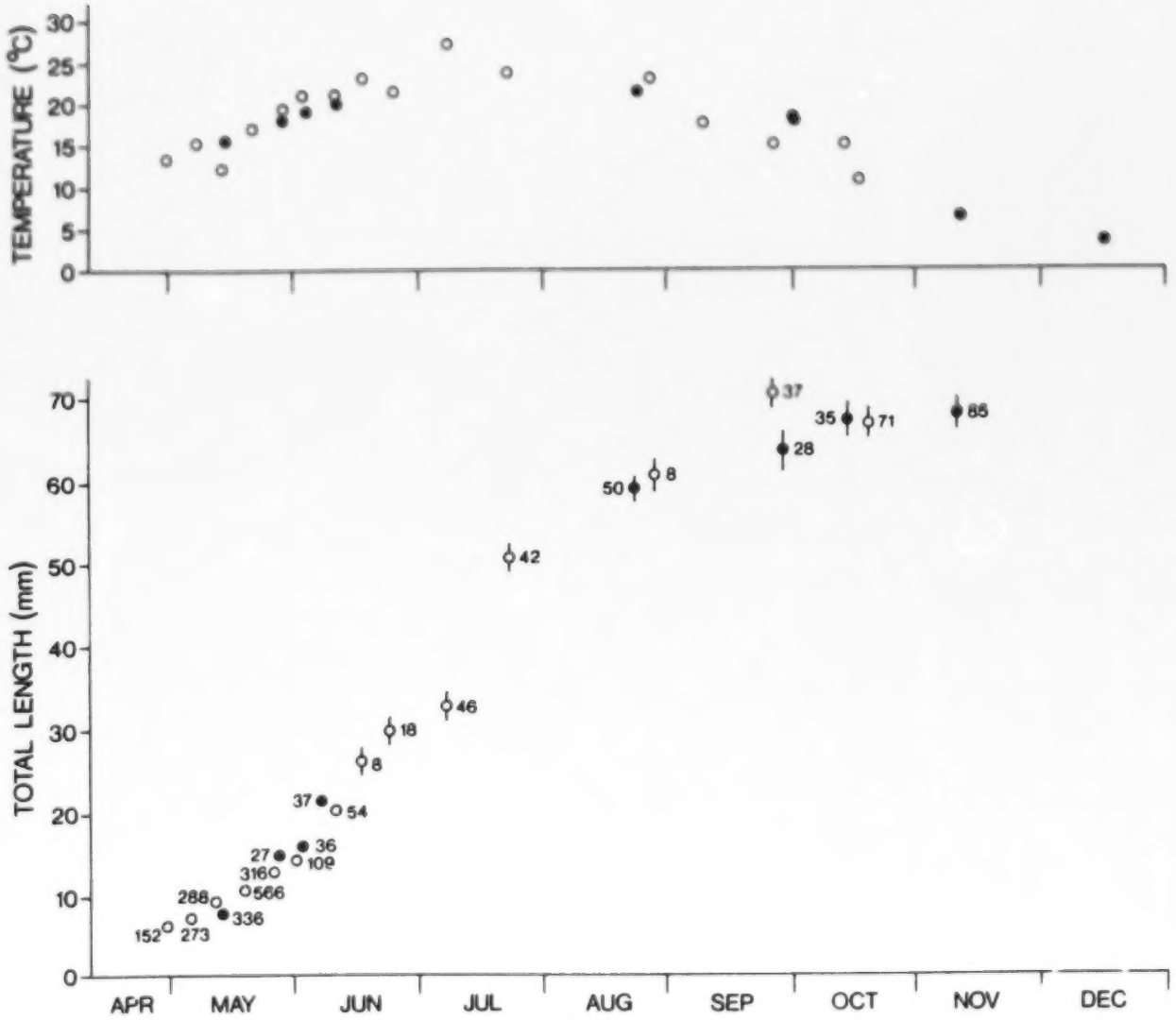

Figure 4. Water temperature (°C, upper graph) and early growth (lower graph) of Perca flavescens in Muscote Bay, 1981 (circles) and 1982 (dots). Vertical bars indicate ± 2 SE.